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CERAMIC FILTER
[SERAMIKKU-FIRUTA]

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[Claims] /2*

[Claim 1] A monolithic type of ceramic filter, comprising:

a cylindrical ceramic porous substrate;

a cell whose cross sections are a pentagon or a higher degree of polygon, or a circle of porous ceramic;

plural numbers of cell line on the cylindrical porous ceramic substrate, each of which has many cells aligned in parallel, and

a cell wall which is formed on the substrate to run straightforwardly at least between two adjacent cell lines.

[Claim 2] The ceramic filter of Claim 1, wherein, the cross section of a cell in a particular cell line is a rectangle in which the upper and the lower lines are parallel, and cells in the cell line are aligned so that the upper and the lower lines form only one straight line, respectively.

[Claim 3] The ceramic filter of Claim 1, wherein, the cross section of a cell in a particular cell line is a rectangle in which the upper and the lower lines are parallel, and cells in the cell line are aligned so that the upper and the lower lines form only one straight line, respectively, and more preferably, a slit-like space is formed by cutting through each cell to expose part of the cell to the external space, and the edge of the cell open externally is sealed.

[Claim 4] The ceramic filter of Claims 1 to 3, wherein, at least one layer of ceramic filter membrane whose pore diameters are smaller than

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* Claim and paragraph numbers correspond to those in the foreign text.

the porous ceramic substrate is formed on the inner circumferential surface of a cell.

[Detailed Explanation of the Invention]

[0001]

[Industrial Field of the Invention] The present invention relates to a ceramic filter of the monolith type which has numerous cells as the path of pre-filtered fluid on a cylindrical substrate which is made of porous ceramic.

[0002]

[Related Art] A ceramic filter is useful to separate a solid component from liquid because, compared with other material such as a polymer membrane, it has higher reliability due to its higher mechanical strength and durability, no degradation by washing with acid/alkaline solution due to its high corrosion resistance, and furthermore, it is possible to control the pore diameter which determines the filtering capability.

[0003] A ceramic filter is made of porous ceramic, and fabricated to various shapes including plates or tubes as the filter material. As shown in Figure 2, a so-called monolith type filter 21 of cylindrical substrate 22 made of porous ceramic on which numerous cells 23 are formed as the path of pre-filtered fluid is widely used.

[0004] The substrate material of porous monolith ceramic is used as the refractory lining, and alternatively, in order to improve the filtering performance while obtaining a large permeability, an additional ceramic filter membrane (the “filter membrane” hereafter), which has pores

of smaller diameter than the pores of the porous ceramic substrate, is formed on the inner circumferential surface of the cell.

[0005] As a monolith filter, in order to obtain the filtering area per the unit volume of the substrate, a rectangular cell of rectangular cross section is also widely used. However, because of the corner angles less than 90° are created on the inner circumferential wall, there are several problems: (1) it is easy to accumulate a layer of residual filtered cake at the corners, which is difficult to remove by counter-washing; and (2) the formed filter membrane becomes thick at the corners and reduces the filtering rate.

[0006] Therefore, it is believed that the monolith type filter preferably has pentagonal or higher degree of polygonal cells, making the corner angle 90° or more, and more preferably has cells of corner angle much more than 90° (e.g., hexagonal cells) or circular cells, which have no corners.

[0007]

[Problems that the Invention is to Solve] The monolith type filter has a honeycomb structure, and similar to other honeycomb structured objects, it may be manufactured by a series of processes of extruding cup soil as the raw material, drying and sintering an extruded object.

[0008] However, a pentagonal or a higher degree of polygonal cell and a circular cell have low stiffness in the vertical direction, and an extruded structure such as the monolith type filter with numerous pores will be easily crushed or deformed by its own weight shortly after

extrusion or an external force caused by the vibration in a post-process of extrusion (such as the sintering process).

[0009] The aforementioned problem is particularly serious for a large filter because it is laid on a surface for sintering. The present invention has considered these problems of the prior art, and provides a monolith type filter which has a filter membrane of uniform thickness formed on the inner circumferential surface of a cell from which a layer of accumulated cake is easily peeled off by counter-washing, and it may be manufactured easily without being crushed and deformed by its own weight or an external force.

[0010]

[Means for Solving the Problems] The inventors of the present invention have diligently studied to solve the above-described problem of the prior art by forming a cell wall which runs straightforwardly across the substrate at least between two adjacent cells in a pentagonal or a higher degree of polygonal cell or a circular cell.

[0011] In other words, the present invention provides a ceramic filter which configures plural numbers of cell lines on a cylindrical porous ceramic substrate, each of which has many cells in parallel and cross sections are a pentagon or a higher degree of polygon, or a circle of porous ceramic, and a cell wall is formed on the substrate to run straightforwardly at least between two adjacent cell lines.

[0012] In the ceramic filter of the present invention, the cross section of a cell in a particular cell line is a rectangle in which the

upper and the lower lines are parallel, and cells in the cell line are aligned so that the upper and the lower lines form only one straight line, respectively, and more preferably, a slit-like void is formed by cutting through each cell to expose part of the cell to the external space, and the edge of the cell open externally is sealed.

[0013] In the ceramic filter of the present invention, at least one layer of ceramic filter membrane whose pore diameters are smaller than the porous ceramic substrate is preferably formed on the inner circumferential wall of a cell as the path of pre-filtered fluid.

[0014]

[Mode for Reducing the Invention to Practice] The present invention is characterized by forming a cell wall that runs straightforwardly between at least two adjacent cells.

[0015] The present invention provides a monolith type filter which has a filter membrane of uniform thickness formed on the inner circumferential surface of a cell, and a layer of the accumulated cake is easily peeled off by counter-washing. Furthermore in manufacturing the filter, it is not crushed or deformed by its own weight or an external force. Below is a detailed description of the present invention. In this specification, "the cross-sectional shape" means the geometrical shape of the cross section which is perpendicular to the direction of forming a cell into the substrate.

[0016] A ceramic filter of the present invention (hereinafter referred to as "filter") is a so-called monolith type filter and has a

honeycomb structure where many cells, which are the path of pre-filtered liquid, are formed in the substrate made of cylindrical porous ceramic.

[0017] The monolith type filter is a percolation filter in which pre-filtered liquid is fed to many cells to percolate the liquid through pores of the porous substrate or a ceramic filter membrane formed on the inner circumferential surface of the cell and then the filter collects filtered liquid coming out of the filter. Because the filter has larger percolation area compared with a plate or a tube filter, the filtering rate is high.

[0018] (1) Substrate

Generally, a monolith type filter uses a cylindrical substrate but the cross sectional shape is not limited to a particular shape but circle, square, rectangle or hexagon may be used. However, a cylinder whose cross section is a circle is preferably used for its ease of extrusion, less deformation while sintered, and ease of sealing to housing.

[0019] The substrate is made of ceramic, which has superior physical strength, durability, and corrosion resistance. The ceramic is not limited to a particular type but alumina, titania, mullite, cordierite, and their mixture may be selected to meet with the specific filtering condition including the resistances to the raw liquid and the washing solution, ease of production, and the manufacturing cost.

[0020] The size of the substrate is not particularly limited but, usually, the total length of the longer side is in the range from 150 to 2000 mm, and the outer diameter of the cylindrical substrate 30 mm and

more. The present invention is preferably applied to a large filter of outer diameter 90 mm and more and length 500 mm and more, which needs to be laid for sintering.

[0021] Because a monolith type filter collects filtered liquid which is percolated through a substrate from the inside of the cell, the substrate should be porous. The porous substrate itself may be used as a filter for some types of raw liquid; however, a ceramic filter membrane formed on the inner circumferential surface of the cell is usually used.

[0022] There are many cells formed in the substrate as the path of raw liquid. The filter of the present invention has plural numbers of aligning cell lines in which there are many cells. Here, each cell is not randomly formed but aligned at least in one direction of the substrate.

[0023] The cell diameter is appropriately selected for the characteristics of raw liquid (including the concentration of the solid content, the size of solid content, and the viscosity) which determine the required filtering area per unit volume, make peeling off adhered solid objects easier by counter washing, and decrease the permeability of the substrate. For example, if the filter is used to percolate tap water, the cell diameter is preferably in the range from 1 to 5 mm. For the structural strength of the substrate, the total volume of cells is preferably less than 80% of the substrate volume.

[0024] A filter of the present invention forms many cells of pentagonal or higher degree of polygonal and/or circular cross section in the substrate. A pentagonal cell or higher degree of polygon such as hexagon, which has

the corner angle more than 90°, or a circular cell, which has no corner angle, may form a membrane of uniform thickness on the inner circumferential wall of the cell, and a layer of filter cake adhered on the inner wall of the cell is easily peeled off with counter washing.

[0025] With the above-described respects, the circular cell is the best while, for obtaining the maximum filtering area per unit volume of the substrate, the hexagonal cell is better with its close-packing configuration. In addition, because the hexagonal cell, which has obtuse angles, may form a uniform filter membrane, and relatively easy to peel off the cake layer from it, the hexagonal cell is particularly preferable. In the present invention, it is not necessary to form the same shape of cells in a filter but several different shapes may be formed.

[0026] As described above, the filter of the present invention has plural numbers of cell lines which aligns cells of pentagonal or higher degree of polygonal and/or circular cross sections, and in addition, at least between a pair of adjacent cells, there is a straight cell wall, running through them (referred to as “straight cell wall” hereafter).

[0027] As shown in Figures 3(a) and 3(b), by forming the straight cell wall 34a-34b between at least a pair of two adjacent cells among a plural number of cell lines 33a, 33b, or 33c may reinforce the strength of the substrate in the direction of the straight cell wall 34a-34b. Therefore, by laying an extruded object so that the straight cell wall 34a-34b orients vertically, it is possible to prevent the extruded object from deformation by its own weight or an external force.

[0028] On the other hand, for instance as shown in Figures 3(c) and 3(d), if cell lines 43 are formed by closed packed circular cells 41 or hexagonal cell 42, all cell walls 44a-44b are formed running zigzag (the "zigzag cell wall")on the substrate, and hence the filter or the cell manufactured from the extrusion may be deformed easily by its own weight or an external force of vibration appeared in a process after extrusion (such as the sintering process).

[0029] The straight cell wall does not need to be formed at both sides of a cell line as shown by the cell line 33b in Figures 3(a) and 3(b) but at least between a pair of two adjacent cell lines.

[0030] Furthermore, the present invention preferably makes the cell cross section shape of cells in a particular cell line a rectangle whose upper side and lower sides are parallel and each side is aligned in a straight line, respectively. This structure may make the straight cell wall at both sides of a particular cell line and the thickness of the cell wall uniform. Namely, while the substrate is extruded, cup soil which is injected into an extrusion mold comes out of the tip of the mold uniformly without any adjustment, and the extruded substrate has less internal stain, which causes less deformation in the sintering process.

[0031] If the thickness of cell walls varies within the substrate, the density of an extruded object would vary unless the diameter of inlet piece from which cup soil is injected is adjusted at various substrate locations. Even an extruded object with varying density would have the effect of the present invention; however, it should be noted that the

contraction while the processes of drying and sintering is different depending on the density, which would crack the extruded object.

[0032] The rectangular cell whose upper and lower sides are parallel includes square, rectangle, parallelogram, trapezoid, and their combinations. Among them, a square cell and a rectangular cell, whose corner angles at the inner circumferential wall are all 90°, are preferably applied because their strength along the cell wall direction is high.

[0033] The filter of the present invention preferably uses the pentagonal or the higher degree of polygonal cell or the circular cell as the basic cell cross section shape, which has advantages of forming a uniform filter membrane and peeling off the cake layer, and also uses a minimum number of the aforementioned rectangle cells, which brings the effect of preventing deformation. If there are too many aforementioned rectangular cells, the uniform filter membrane may not be obtained or the cake layer would be difficult to remove. However, it is possible to control these disadvantages by trimming the corners of the rectangular cell (to make the cell an octagon-like shape or to make the corners round).

[0034] The number of the “particular cells” which should be rectangles is different for different filter size and shape, however, for example, if there are 61 cell lines on a cylindrical substrate of the outer diameter 180 mm x the length 1000 mm, the rectangular cell lines are approximately 9 (i.e., 9 straight cell lines on each side, a total of 18 cell lines are formed), the effect of preventing deformation will be achieved.

[0035] (2) Slit

In a large filter, some of plural numbers of cell lines may be broken to form slit-like space (referred to as "slit" hereafter) which connect part of the cells to the external space (Japanese Patent Application Kokai No. 10-328003).

[0036] The above structure has several advantages: easy collection of filtered liquid from the central part of the cell, resulting in an increase of the permeability (or the filtering capacitance) of the filter more than 10 times, and substantial improvements of the distributions of permeability in the filter and the back-pressure of counter washing.

[0037] The structure of the present invention may apply to a filter with the aforementioned slit. In this case, the "particular cell line" of rectangular cells preferably has the slit.

[0038] The reason for the selection of the cell line is that when a blade such as an electro-deposited diamond cutter cuts a cell line (the "slit-forming cell line") before or after sintering the substrate to expose part of the cell line to the external space, if the cell line is the zigzag which has hexagonal or circular inner wall, the blade would cut into the cell following the zigzag wall and damage the cell wall between adjacent cell lines.

[0039] On the other hand, in the "particular" cell line of rectangular cells, the inner cell wall is aligned with a straight line, and thus the blade will not damage the cell wall even if it cuts into the cell following the straight inner wall. The opening of the slit-forming cell at the edge

of the substrate is hermetically sealed with sealant in order to prevent the contamination of the filtered liquid with the raw liquid because the raw liquid does not flow into the area. Therefore, it is not necessary to form a filter membrane on the inner wall of a cell, and thus the cake layer will not be accumulated thereon, which is another preferable advantage of the rectangle cell.

[0040] (3) Fitter membrane

As described above, the present invention preferably forms a porous ceramic membrane of small pore diameter (referred to as "filter membrane" hereafter) on the inner circumferential wall of a cell as the path of the raw liquid.

[0041] With this structure, because the porous membrane primarily performs the filtering function, it is possible to increase the pore diameter of the substrate in the range from 1 to 100 μm, and thus increase the permeability of the filter.

[0042] The filter membrane is a thin film of pore diameter less than 10μm, and, similar to the substrate, it is made of ceramic. The filter membrane may be adhered to the inner wall of the substrate by sintering a slurry film containing a ceramic aggregate grain (referred to as "aggregate grain" hereafter) formed on the inner circumferential wall of the substrate.

[0043] For example, the slurry may be prepared by dispersing the aforementioned aggregate grain into a dispersion medium such as water, and adding an organic binding agent, a pH modifier, and a surfactant, as

required, and then, by applying a well-known method such as the dip coating method and the filter membrane forming method disclosed by Japanese Patent Application Kokoku 63-66566, a filter membrane is formed on the inner wall of a cell, followed by sintering at temperature 1300°C.

[0044] The type of ceramic for the aggregate grain is not particularly limited but alumina, titania, mullite, zirconia, silica, spinal, and their mixture may be used. However, the raw material of aggregate grain preferably has a controlled grain size, is easy to obtain, may form stable slurry, and has high corrosion resistance (e.g., alumina). The pore size of the filter membrane is easier to control than the aggregate grain. A single layer of the filter membrane is preferred but two or more layers may be formed as well.

[0045]

[Embodiment of the Invention] An embodiment of the present invention is further described in detail. However, the scope of the present invention is not limited by the embodiment disclosed therein.

[0046] (Basic structure of filter) Embodiment 1 and Comparative Example 1 are both cylinders of the diameter 180 mm, the length 1000 mm, and have the same honeycomb structure made of alumina of the average pore diameter 20μm as measured with the mercury press-in method, and the porosity 40% as measured with the JIS immersion method. The honeycomb structure has 61 cell lines each of which has up to 53 cells, a total of 2200 cells.

[0047] By using an electro-deposited diamond cutter, slits are formed at the center along the length direction of an extruded cylindrical

substrate at every 6 cell lines. The slit width is 1.2 mm which is smaller than the height of a cell in the slit-forming line, and each edge of slit is trimmed round. After forming slits, the extruded substrate is dried and sintered to make a finished substrate.

[0048] As shown in Figures 1 and 4, the edge openings of slit-forming lines 6 and 56, the cell substrate 2 and 52 are filled with sealant 5 and 55, and then hermetically sealed by sintering them. Furthermore, alumina filter membranes 1 and 51 of the average pore diameter 0.1 μm and the thickness 10 μm are formed on the inner circumferential wall of cells in cell lines other than slit-forming lines 6 and 56 of the cell substrate 2 and 52.

[0049] (Embodiment 1) Figure 1 shows a schematic diagram of the filter as an embodiment of the present invention. In filter 1 of the embodiment 1, a slit-forming cell line 6 is configured with a rectangular cell 3a of the cell width 2.5 mm and height 2 mm, whereas the cell line adjacent to the slit-forming cell line 6 is configured with a pentagonal cell 3b, which is similar to the home base of the baseball game, of the cell width 2.5 mm and the height up to 2.4 mm, and the other cell lines are configured with hexagonal cells 3c of the opposite side length 2.5 mm, where the pentagonal cell 3b is aligned with the rectangular cell 3a along the height direction. The thickness of cells are all 0.65 mm. Here are straight cell walls 7 above and below the cell line of rectangular cells 3a in the filter 1.

[0050] (Comparative Example 1) Figure 4 shows a schematic diagram

of Comparative Example 1. The filter 51 of Comparative Example 1 is configured with cells all of thickness 0.65 mm, hexagonal cells 53 of the opposite side length 2.5 mm. There are zigzag cell walls between cell lines 51.

[0051] (Result) Embodiment 1 and Comparative Example 1 are examined for their deformation while being sintered. Table 1 shows the result of defamations of 3 units of Embodiment 1 and Comparative Example 1 where the difference between the maximum and the minimum outer diameters of the filter edge surface after the sintering process is calculated for each sample and their average values (n=3).

[0052]

[Table 1]

(単位)	ｻﾝﾌﾟﾙNo.	最大外径 (mm)	最小外径 (mm)	差 (mm)
実施例1	1	180.87	180.64	0.23
	2	180.02	179.63	0.39
	3	180.62	180.28	0.33
	平均値	180.50	180.17	0.33
比較例1	1	182.18	178.14	4.04
	2	182.00	178.05	3.95
	3	183.50	179.74	3.76
	平均値	182.56	178.64	3.92

Key:

(Unit)	No of samples	Max. diameter (mm)	Min. diameter (mm)	Difference (mm)
Embodiment 1				
	Average			
Comparitive				

Example 1				
	Average			

[0053] Filters of Comparative Example 1 showed the average difference of the maximum and the minimum outer diameters of the filter edge surface is 3.92 mm, which is large due to deformation during the sintering process. Embodiment 1 showed the average difference of the maximum and the minimum outer diameters of the filter edge surface is 0.33 mm, indicating that there is almost no deformation during the sintering process. In other words, filters of Embodiment 1 showed the effect of producing the structure which has straight cell wall 7 formed between adjacent cell lines, and cells in a particular cell line are rectangular cells 3a.

[0054] The filters of Embodiment 1 have careful combinations of rectangular cells 3a, pentagonal cells 3b, and hexagonal cells 3c for achieving the uniform wall thickness of cells and the close packed configuration.

[0055] The above structure configures straight cell walls at both sides of a particular cell line and prevents deformation. In addition, because the structure has a uniform thickness of the cell wall, when the substrate is formed by extrusion, cup soil put into an extrusion mold is extruded uniformly from the mold without any adjustment, and the extruded substrate has less internal stain. Therefore, the extruded product causes less deformation in the sintering process.

[0056] Furthermore, because the slit-forming line hermetically seals its cell opening at the edge of the substrate. Although the filtering area

is reduced by sealing, the minimum slit height is the shortest length that a slit may be formed, and hence the reduction of the filtering area may be kept minimal.

[0057] The filter of the present invention may include a configuration of the straight cell wall with a different cell-forming pitch, or the cell configuration shown in Figure 3(b), in addition a closed packed cell configuration to obtain the effect of less deformation. However, because the former could cause a crack due to internal strain while sintering, and the latter reduces the number of cells in a filter (or the filtering area), the structure of Embodiment 1 is preferred.

[0058] The structure of Embodiment 1 may obtain the same or more effect with the different cell forming pitch as long as the wall thickness is uniform across the substrate. For example, as show in Figure 5, it is possible to form rectangular cells 3a displaced by half a pitch from the pentagonal cells 3b.

[0059]

[Effects of the Invention] The filter of the present invention configures cells whose cross sectional shape is a pentagon or a higher degree of polygon or a circle to form a filter membrane of uniform wall thickness on the circumferential inner wall, and the cake layer adhered on the inner circumferential wall of a cell may be easily peeled off with counter-washing. Furthermore, because there is a straight cell wall running through between adjacent cell lines on the substrate, it is possible to prevent the filter from being deformed by its own weight or an external

force.

[Brief Explanation of the Figure]

[Figure 1] A schematic diagram of a filter of Embodiment 1 of the present invention where (a) is an expanded cross section and (b) is a strabismus figure of the filter.

[Figure 2] A strabismus figure of a filter of the prior art.

[Figure 3] A schematic diagram of cell walls to be formed between cell lines where (a) and (b) are the filter of the present invention, and (c) and (d) are the filter of the prior art.

[Figure 4] A schematic diagram of the filter of Comparative Example 1 where (a) is an expanded cross section and (b) is a strabismus figure of the filter.

[Figure 5] Expanded edge surface of a filter of another embodiment of the present invention.

[Explanation of the Reference Numerals]

1 … Filter

2 … Substrate

3 … Cell (3a … rectangular cell, 3b … pentagonal cell, 3c … hexagonal cell)

4 … Silt

5 … Sealant

6 … Slit-forming line

7 … Straight cell wall

21 … Filter

22 … Substrate

23 … Cell

31 … Circular cell

32 … Hexagonal cell

33 … cell line

34 … Straight cell wall

41 … Circular cell

42 … Hexagonal cell

43 … Cell line

44 … Zigzag cell wall

51 … Filter

52 … Substrate

53 … Cell

54 … Slit

55 … Sealant

56 … Slit-forming line

Figure 1

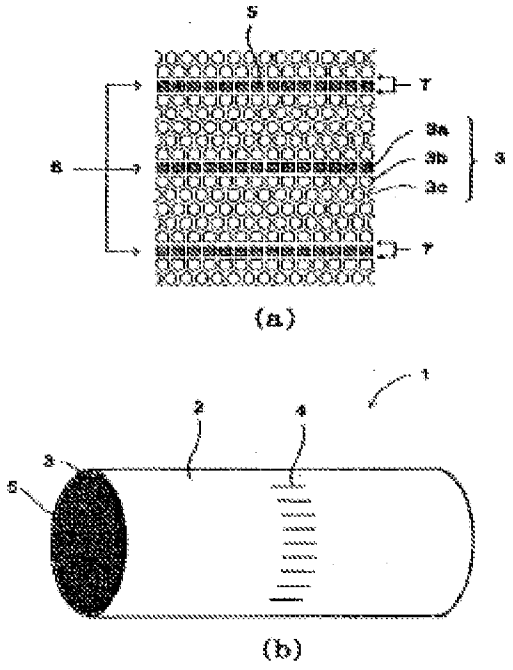

Figure 2

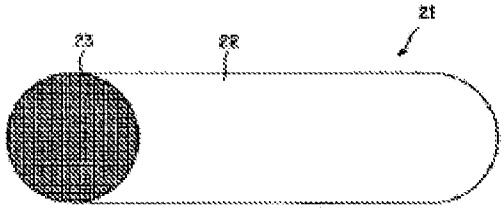

Figure 3

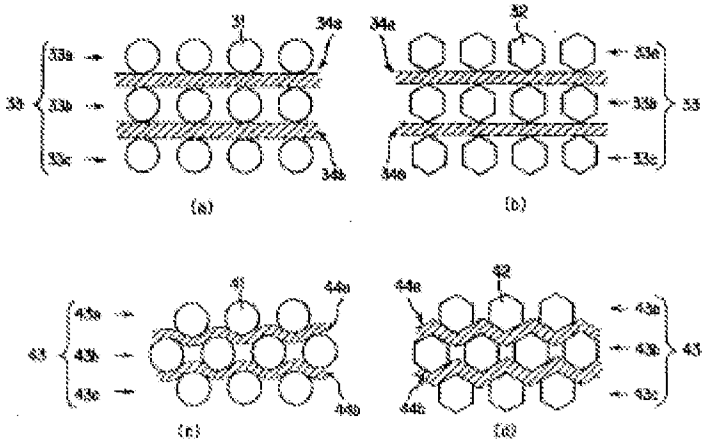

Figure 4

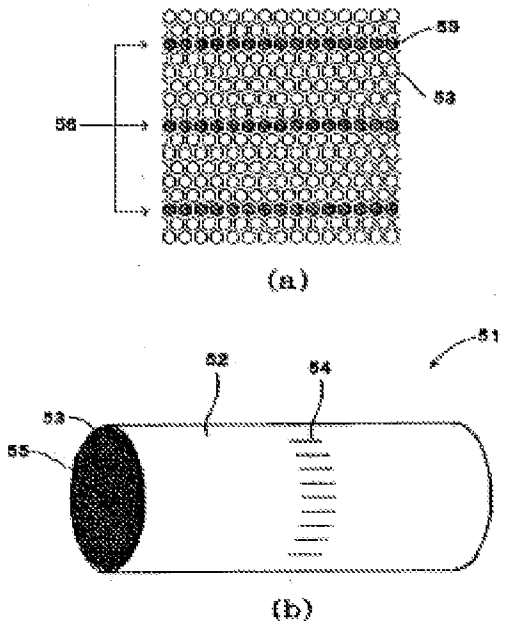

Figure 5